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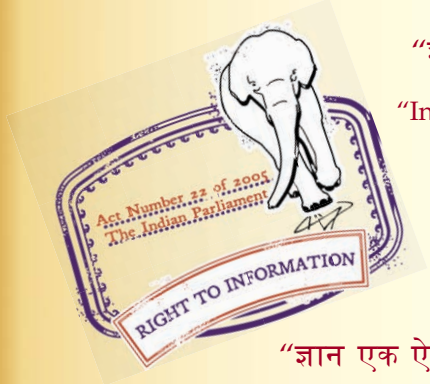
IS 3231-3-4 (1987): Electrical Relays for Power System Protection, Part 3: Requirements for Particular Group of Relays, Section 4: Directional Relays and Power Relays [ETD 35: Power Systems Relays]



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"Invent a New India Using Knowledge"

"ज्ञान एक ऐसा खजाना है जो कभी चुराया नहीं जा सकता है"
Bhartṛhari—Nītiśatakam
"Knowledge is such a treasure which cannot be stolen"

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IS : 3231 (Part 3/Sec 4) - 1987

(Reaffirmed 2001)

Indian Standard

SPECIFICATION FOR ELECTRICAL RELAYS FOR POWER SYSTEM PROTECTION

PART 3 REQUIREMENTS FOR PARTICULAR GROUP OF RELAYS

Section 4 Directional Relays and Power Relays

UDC 621·316·925 : 681·584·58

BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

Gr 5 *October* 1987

Indian Standard

SPECIFICATION FOR ELECTRICAL RELAYS FOR POWER SYSTEM PROTECTION

PART 3 REQUIREMENTS FOR PARTICULAR GROUP OF RELAYS

Section 4 Directional Relays and Power Relays

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(*Continued on page* 19)

Indian Standard

SPECIFICATION FOR ELECTRICAL RELAYS FOR POWER SYSTEM PROTECTION

PART 3 REQUIREMENTS FOR PARTICULAR GROUP OF RELAYS

Section 4 Directional Relays and Power Relays

0. FOREWORD

0.1 This Indian Standard (Part 3/Sec 4) was adopted by the Indian Standards Institution on 26 February 1987, after the draft finalized by the Relays Sectional Committee had been approved by the Electrotechnical Division Council.

0.2 This standard is one of the series of standards being brought out to cover requirements of protection relays. General introduction to this series is given in IS : 3231 (Part 0)-1986*, which may be seen.

0.3 According to classification on hierarchical basis [*see* IS : 3231 (Part 0)-1986*], this standard is a third level document.

0.4 This standard should be read in conjunction with IS : 3231 (Part 2/Sec 2)-1987† to which a reference has been made, as these relays constitute a particular subfamily (group) of measuring relays with more than one input energizing quantity.

0.5 In preparing this standard, assistance has been drawn from the following:

IEC Publication 225-12 (1980) Electrical relays: Part 12 Directional relays and power relays with two input energizing quantities. International Electrotechnical Commission.

BS 142 : Section 4.2 : 1984 Electrical protection relays: Part 4 Requirements for multi-input energizing quantity relays Section 4.2 Specification for directional relays and power relays. British Standards Institution.

*Specification for electrical relays for power system protection: Part 0 General introduction and list of parts.

†Specification for electrical relays for power system protection: Part 2 Requirements for principal families, Section 2 General requirements for measuring relays.

0.6 The requirements in this standard relating to phase angle (direction) may be combined with requirements relating to other characteristics (for example, current) specified in other standards in this series so as to cover combinations, such as directional current relays.

1. SCOPE

1.1 This standard (Part 3/Sec 4) specifies the performance requirements of directional relays and power relays with two input energizing quantities which constitute a particular sub-family of measuring relays and the parameters whose values are to be declared by the manufacturer of such relays. It also specifies methods of presenting the characteristics and performance of these relays.

1.2 This standard excludes impedance relays and deals specifically with relays measuring phase angle (direction) and power.

1.3 For particular cases, supplementary requirements may be agreed between the manufacturer and the user or may be specified in the lower level standard.

1.4 This standard applies only to the relays in new condition.

2. TERMINOLOGY

2.0 For the purpose of this standard, the following definitions, in addition to those given in IS : 1885 (Part 9)-1986*, shall apply.

2.1 Directional (Phase Angle Measuring) Relay — A relay with two input energizing quantities and which, by its design, is intended to respond only to the relative phase position of a current or voltage with respect to another current or voltage reference.

2.2 Power Relay — A relay with two input energizing quantities, current and voltage and which, by its design, is intended to respond only to power.

2.3 Characteristic Angle of Power and Directional Relays — The angle between the phasers representing the two energizing quantities, which is used for the declaration of the performance of the relays.

NOTE 1 — Particularly for electromechanical relays, it is usually the angle at which the maximum sensitivity occurs.

*Electrotechnical vocabulary: Part 9 Electrical relays (*first revision*).

NOTE 2 — A given relay may have more than one characteristic angle. On the other hand, a given relay may be connected in alternative modes; for example by links, with a variety of connection angles. The combination of a given characteristic angles with a given connection angle results in an overall performance effective for a given application.

2.4 Connection Angle of Power and Directional Relays (*see also* **Note 2 under 2.3**) — The angle between the voltages which are identified with the phasers representing the two energizing quantities.

2.5 Directional Sensitivity — The minimum value of the input energizing quantity at which the relay operates, the other input energizing quantity being at its reference value and the angle between the input energizing quantities being the characteristic angle.

3. STANDARD VALUES

3.1 Input and Auxiliary Energizing Quantities and Frequency — The standard values of input and auxiliary energizing quantities and of frequency are as specified in IS : 3231 (Part 2/Sec 2)-1987*.

3.1.1 *Effective Range of Input Energizing Quantities* — There are no standard effective ranges of input energizing quantities. These shall be declared by the manufacturer.

3.2 Characteristic Angle and Connection Angle

3.2.1 *Value of Characteristic Angle and Connection Angle* — There are no standard values of the characteristic and connection angles. The characteristic angle, and the connection angle, if any, shall be declared by the manufacturer. Other connection angles for various applications may also be declared by the manufacturer (*see* Note 2 under **2.3**).

3.2.2 *Setting Range of Characteristic Angle* — There are no standard setting ranges. The setting ranges of the characteristic angle, if any, shall be declared by the manufacturer.

3.3 Specified Times — There are no standard rated values for specified times. The manufacturer shall declare whether the relay has independent or dependent specified times.

NOTE — Dependent time characteristics are mainly applicable to power relays. For a directional relay, for which the characteristic quantity is angle, dependent times are applicable only in special cases.

3.3.1 *Independent Specified Time Relays* — Independent specified times shall be declared by the manufacturer.

*Specification for electrical relays for power system protection: Part 2 Requirements for principal families, Section 2 General requirements for measuring relays.

3.3.2 *Dependent Time Relays with Increasing Function* — The shape of the characteristic curve shall be declared by the manufacturer (*see* **5**).

3.3.3 *Dependent Time Relays with Decreasing Function* — The shape of the characteristic curve shall be declared by the manufacturer (*see* **5**).

The most common characteristic curves for relays with decreasing function are given in **2.1.2** of IS : 3231 (Part 3/Sec 2)-1987*.

NOTE — Dependent time characteristics are mainly applicable to power relays. For a directional relays, for which the characteristic quantity is angle, dependent times are applicable only in special cases.

3.4 Resetting Times — There are no standard values of resetting times. The values shall be declared by the manufacturer.

3.5 Standard Reference Values of Influencing Quantities and Factors and Standard Values of Their Nominal and Extreme Ranges

3.5.1 *Standard Reference Values of Influencing Quantities and Factors* — The standard reference conditions are given in Table 1 of IS : 3231 (Part 2/Sec 2)-1987†. In addition, the standard conditions specified in Table 1 apply to directional relays and power relays.

3.5.2 *Limits of the Nominal Ranges of the Influencing Quantities and Factors* — The standard values are specified in Table 2 of IS : 3231 (Part 2/Sec 2)-1987†. In addition, the standard values specified in Table 2 apply to power and directional relays.

3.6 Characteristic Quantities and Setting Range(s) — There are no standard rated values of either characteristic quantity(ies) or setting range(s). These values and the limits of setting range(s) shall be specified by the manufacturer.

3.7 Resetting and Disengaging Values — The resetting and disengaging values shall be declared by the manufacturer. In the case of power relays, these values shall be specified as ratios or percentage. In the case of directional relays, they shall be specified in degrees at the boundaries.

*Specification for electrical relays for power system protection: Part 3 Requirements for particular group of relays, Section 2 Dependent specified time measuring relays.

†Specification for electrical relays for power system protection: Part 2 Requirements for principal families, Section 2 General requirements for measuring relays.

TABLE 1 STANDARD REFERENCE CONDITIONS AND TEST TOLERANCES OF INFLUENCING QUANTITIES AND FACTORS

(*Clause* 3.5.1)

Influencing Quantity or Factor		Reference Condition	Test Tolerances
Characteristic and input energizing quantities	Reference input energizing quantity for operating and resetting times:		
	a) Power relays	500 percent of the operating value	
	b) Directional relays	Rated value	
	Non-reference input energizing quantity	As declared by the manufacturer	
	Phase angle between input energizing quantities (*see* Note 1)	Declared characteristic angle or range of angles	± 2°
	dc component in ac; transient	Zero (*see* Note 2)	5 percent of peak ac value
	Setting value(s), where setting adjustments are possible	As declared by the manufacturer	
Auxiliary energizing quantities	dc component in ac; transient	Zero (*see* Note 2)	5 percent of peak ac value

NOTE 1 — A reference phase angle is necessary for directional relays when measuring time and sensitivity.

NOTE 2 — In the special case of relays in which polyphase measurements are made on a single relay, the manufacturer shall define which of the input currents shall be under reference conditions.

4. OPERATION AND ACCURACY

4.1 Operation

4.1.1 *Operating Characteristics* — The manufacturer shall declare the operating characteristics of the relay under reference conditions, including the reference setting value.

NOTE — If desirable, the manufacturer may declare the operating characteristics in terms of the combined effect of the characteristic angle and the connection angle.

TABLE 2 STANDARD VALUES OF THE LIMITS OF THE NOMINAL RANGE OF INFLUENCING QUANTITIES AND FACTORS

(*Clause* 3.5.2)

Influenc ng Quantity or Factor		Nominal Range
Characteristic and input energizing quantities	Reference input energizing quantity (voltage)	a) Power relays — 50 to 110 percent of rated value b) Directional relays — 3 to 110 percent of rated value (*see* Note 1)
	Non-reference input energizing quantity	As declared by the manufacturer
	Phase angle between input energizing quantities	a) Power relays : ± 60° from stated unity power factor condition (*see* Note 2) b) Directional relays : As declared by the manufacturer
	Frequency	As declared by the manufacturer
	Waveform	
	dc component in ac; steady state and transient	
Auxiliary energizing quantities	Voltage or current	As declared by the manufacturer
	Frequency	
	Waveform	
	ac component in dc (ripple)	0 to 12 percent of the rated dc value (*see* Note 3)
	dc component in ac; steady state and transient	As declared by the manufacturer

Note 1 — For earth fault directional relays used on systems which are not solidly earthed, the nominal range of voltage shall be 3 to 190 percent of rated voltage.

Note 2 — Account should be taken of phase or neutral connections or both.

Note 3 — This value of tolerance applies to peak-ripple factor.

4.1.2 *Operating and Resetting Times* — The manufacturer shall declare the operating and resetting times of the relay under reference conditions, including the reference setting value. The initial and final values of the input energizing quantities shall also be declared by the manufacturer.

4.1.2.1 *Measurement of operating time for power relays* — Reference condition for determining operating time shall be as follows:

a) Current — 500 percent of operating current at rated voltage,

b) Voltage — Rated voltage ± 5 percent, and

c) Phase angle between input — Characteristic angle.
energizing quantities

NOTE — The voltage should be maintained at its rated value and the current switched accordingly.

For directional relay the reference magnitude of current shall be the rated current.

4.1.3 *Effective Ranges* — The manufacturer shall declare the effective ranges of voltage, current and the phase angle.

4.1.4 *Reference Setting* — The manufacturer shall declare the reference setting value(s) of the relay. All other settings shall be regarded as influencing factors.

4.1.5 *Output Circuits*

4.1.5.1 For directional and power relays the following shall apply:

The relay shall remain inoperative:

a) with rated voltage applied, power in the non-operative direction and when current up to 20 times the rated current at the relay characteristic angle are applied or switched off; and

b) with zero voltage applied and when currents up to 15 times the rated current are applied or switched off.

NOTE — For design tests it is important to take into account that, in service, the impedance of the voltage source may still be connected across the relay voltage input. Details of the test procedure should be agreed between the manufacturer and the purchaser.

4.1.5.2 For directional relays the following shall apply:

With 3 percent of the rated voltage applied to the voltage input and with the angle between the phasers of the energizing quantities being the characteristic angle, the input current required to cause operation shall not exceed 20 times the operating current.

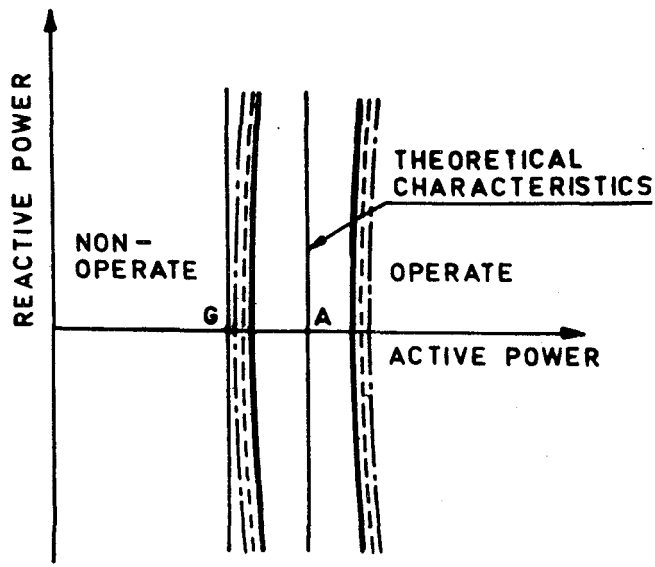
4.2 Accuracy

a) For power and directional relays, considerations of accuracy apply, under reference conditions, to the operating characteristic and to the dependent and independent times for specified time relays. For these items, the manufacturer shall declare the assigned error as defined in IS : 3231 (Part 2/Sec 2)-1987*, and

*Specification for electrical relays for power system protection: Part 2 Requirements for principal families, Section 2 General requirements for measuring relays.

b) For directional relays, the following shall apply:
Unless otherwise specified, with rated current of the relays, the relay shall operate when the measured angle is less than $90\left(1-\frac{E}{100}\right)$ degrees and shall not operate when the measured angle is greater than $90\left(1+\frac{E}{100}\right)$ degrees from the relay characteristic angle current vector giving the maximum torque, where E is the declared assigned error of the relay, all other influencing factors and quantities being at their reference.

4.2.1 *Operating Characteristics* — The accuracy of the operating characteristics may be shown graphically as in Fig. 1, 2, 3 and 4 by maximum and minimum lines over the effective range(s). Other methods declared by the manufacturer may also be used, including non-graphical methods.



_____ error limits and variations for U = 100 percent of rated voltage
..... error limits and variations for $U = k_1$ percent of rated voltage
— . — error limits and variations for $U = k_2$ percent of rated voltages

$100 > k_1 > k_2$

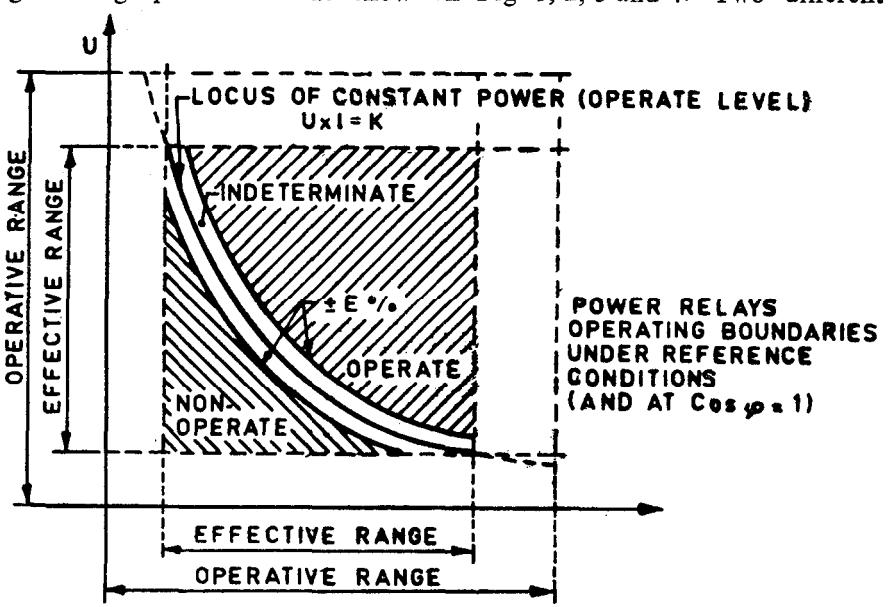
G = basic value for relay with dependent time characteristic
A = theoretical operating value

FIG. 1 OPERATING CHARACTERISTIC OF A POWER RELAY

4.2.2 *Operating and Resetting Times* — The accuracy of the operating and resetting times may be shown graphically as in Fig. 5, 6, 7, 8 and 9 by maximum and minimum lines over the effective range(s). Other methods declared by the manufacturer may also be used, including non-graphical methods.

5. METHODS OF PRESENTING RELAY CHARACTERISTICS AND PERFORMANCE

5.1 Operating Characteristics — The operating characteristics can be given in graphical form as shown in Fig. 1, 2, 3 and 4. Two different



The quantities with effective ranges are U, I, ϕ (it may be considered that one or more of these are influencing factors).

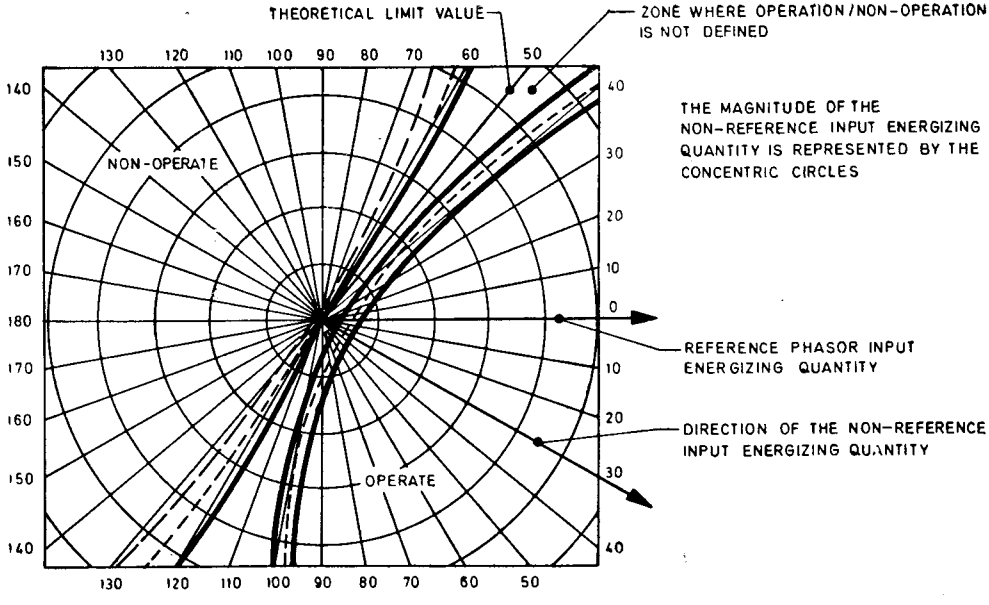
The relay will operate at the declared level of power $\pm E$ percent provided that all quantities I, U, and ϕ are within their effective ranges:

For example $I = 0{\cdot}05$ to $10\ I_n$, $U = 0{\cdot}01\ U_n$ to $1{\cdot}25\ U_n$, $\phi = -85°$ to $+85°$

NOTE — The effective range of ϕ need not be declared provided that the effective ranges of I and U limit the range of ϕ to within that which would have been claimed.

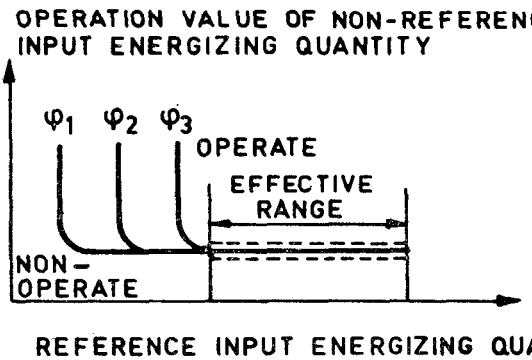
The method is shown for over-power relays but can also be used for under-power relays.

FIG. 2 OPERATING CHARACTERISTIC OF A POWER RELAY AT A GIVEN ANGLE



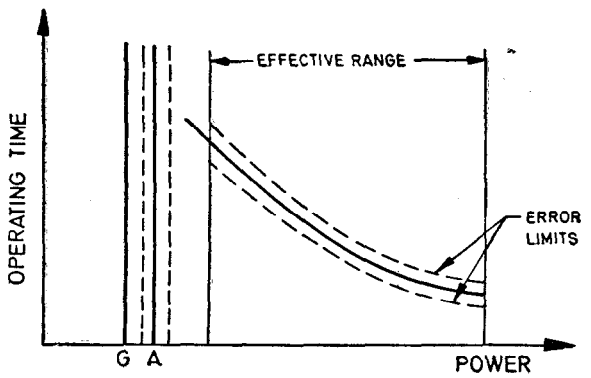
——— limit at 100 percent of rated value of reference input energizing quantity
..... limit at k_1 percent of rated value of reference input energizing quantity
— - — limit at k_2 percent of rated value of reference input energizing quantity
$100 > k_1 > k_2$

FIG. 3 OPERATING CHARACTERISTIC OF A DIRECTIONAL (ANGLE MEASURING) RELAY



φ_1, φ_2, φ_3 = angle deviation from the characteristic angle

FIG. 4 OPERATING CHARACTERISTIC OF A DIRECTIONAL RELAY WITH VARYING VALUES OF THE REFERENCE INPUT ENERGIZING QUANTITY



G = basic value
A = theoretical operating value

FIG. 5 OPERATING TIME FOR A DEPENDENT TIME POWER RELAY

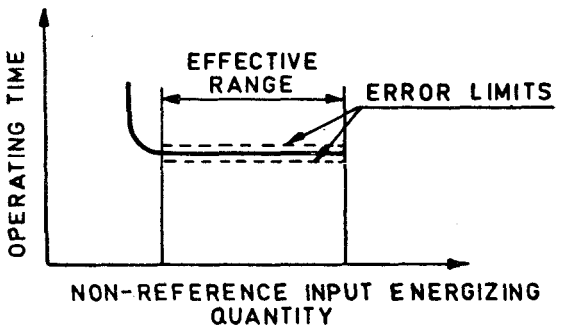


FIG. 6 OPERATING TIME FOR AN INDEPENDENT TIME POWER RELAY

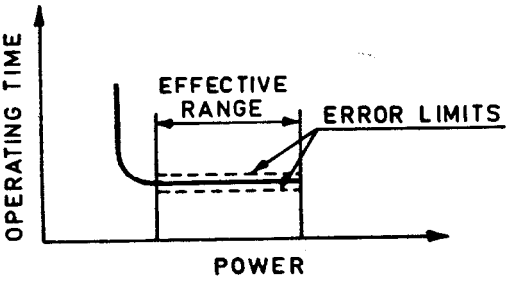
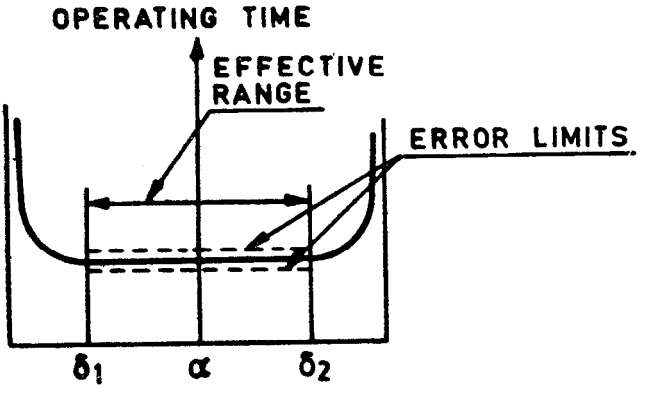


FIG. 7 OPERATING TIME FOR A SPECIFIED TIME DIRECTIONAL RELAY



α = characteristic angle
δ_1, δ_2 = boundary angles

FIG. 8 OPERATING TIME FOR A SPECIFIED TIME DIRECTIONAL RELAY

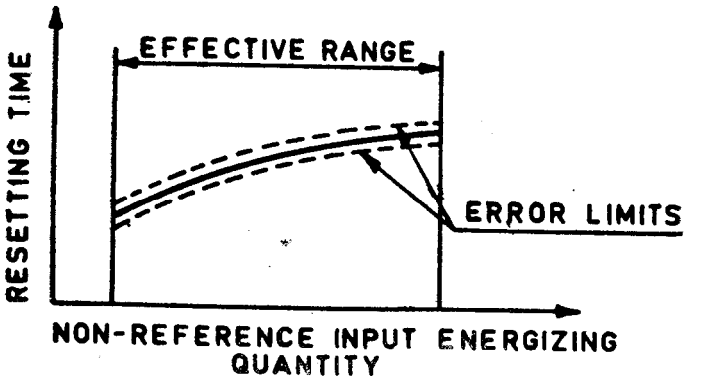


FIG. 9 RESETTING TIME FOR A SPECIFIED TIME DIRECTIONAL RELAY

ways of presenting operating characteristics are shown for both power and directional relays. Of these two methods, the first method for each relay type is the preferred method (Fig. 1 and 3).

NOTE — Methods other than graphical may be used for describing the performance.

5.2 Operating Time — The operating time for power and directional relays may be shown in graphical form as in Fig. 5, 6, 7 and 8.

5.3 Resetting Time — The resetting time for power and directional relays may be shown in graphical form as in Fig. 9.

6. TERMINAL REQUIREMENTS

6.1 The terminal requirements shall be as specified in 5 of IS : 3231 (Part 2/Sec 2)-1987*.

7. MECHANICAL REQUIREMENTS

7.1 The mechanical requirements shall be as specified in 9 of IS : 3231 (Part 2/Sec 2)-1987*.

8. VALUES OF THE LIMITS OF THE OPERATIVE RANGE OF THE AUXILIARY ENERGIZING QUANTITY

8.1 The values of the limits of the operative range of the auxiliary energizing quantities shall be as specified in IS : 3231 (Part 2/Sec 2)-1987*.

9. CONTACT PERFORMANCE

9.1 The requirements as specified in IS : 3231 (Part 1/Sec 1)-1987† shall apply.

10. RATED BURDEN

10.1 The rated burden shall be as specified in 8 of IS : 3231 (Part 2/ Sec 2)-1987*.

11. INSULATION

11.1 The insulation requirements as specified in IS : 3231 (Part 1/Sec 2)-1986‡ shall apply.

*Specification for electrical relays for power system protection: Part 2 Requirements for principal families, Section 2 General requirements for measuring relays.

†Specification for electrical relays for power system protection: Part 1 General requirements, Section 1 Contact performance.

‡Specification for electrical relays for power system protection: Part 1 General requirements, Section 2 Insulation tests.

12. MARKING AND DATA

12.1 The marking and data requirements shall be as specified in IS:3231 (Part 2/Sec 2)-1987*.

13. HIGH FREQUENCY DISTURBANCE TEST

13.1 For static relays, the requirements relating to a high frequency disturbance test as specified in IS : 3231 (Part 1/Sec 3)-1986† shall be applicable.

14. TESTS

14.1 General

14.1.1 The classification of tests and requirements for routine testing shall be in accordance with **12** of IS : 3231 (Part 2/Sec 2)-1987*.

14.1.2 Unless otherwise specified, the test methods shall be as given in **14.2** to **14.4.**

14.2 Test Methods Related to Accuracy and Operating Characteristics

14.2.1 *Test Conditions*

14.2.1.1 All influencing quantities and factors shall be at the reference values (within the specified test tolerances), unlesss otherwise specified in this standard.

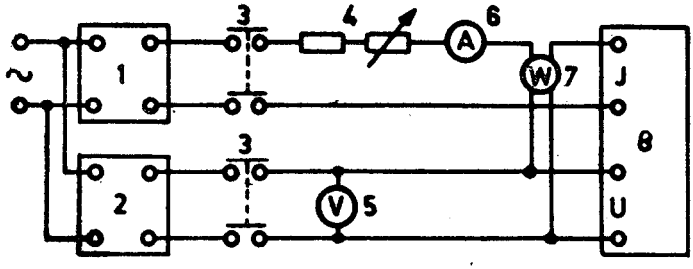
14.2.1.2 The auxiliary energizing quantities shall be at the rated value for all tests, unless otherwise specified in this standard.

14.2.1.3 The method of applying the input energizing quantities (that is, suddenly or gradually) shall be declared by the manufacturer if not specified in this standard.

14.2.2 *Test Circuits and Methods for Measuring Relays Characteristics* — Figure 10 shows an example of a test circuit with adjustable voltage and current energizing the relay under test. The circuit is suitable for testing power relays as well as directional relays with current and voltage as the input energizing quantities. For directional relays with current

*Specification for electrical relays for power system protection: Part 2 Requirements for principal families, Section 2 General requirements for measuring relays.

†Specification for electrical relays for power system protection: Part 1 General requirements, Section 3 High frequency disturbance test for static relay.



1. Variable voltage source
2. Variable voltage source with phase shifting
3. Switching device
4. Series resistor
5. Voltmeter
6. Ammeter
7. Wattmeter or power factormeter
8. Relay under test

FIG. 10 EXAMPLE OF TEST CIRCUIT

and current, or voltage and voltage as input energizing quantities, the test circuit requires modification.

14.2.2.1 *Operating characteristics*

a) For power relays, the tests are performed at constant values of voltage within the effective range. For different phase angles, the current shall be slowly varied to determine the operate and non-operate levels.

b) For directional relays, one of the input energizing quantities shall be applied with a constant value within its effective range. The other input energizing quantity and the phase angle shall be appropriately varied.

14.2.2.2 *Operating and resetting time characteristics*

a) For a power relay, the operating time test is performed with the voltage at its rated value and the current suddenly increased from an initial value of zero to 500 percent of rated value. The resetting time test is performed with the current suddenly decreased from 500 percent of rated value to zero. The phase angle shall be equal to the characteristic angle.

b) For relays with dependent time characteristics, tests shall be performed at various values within the effective range of power (*see* Fig. 5).

c) For directional relays, the manufacturer shall declare the methods of determining the operating and resetting times and present this information in a form similar to that shown in Fig. 7, 8 or 9.

14.3 Thermal Tests — The tests for thermal requirements shall be carried out in accordance with **13** of IS : 3231 (Part 2/Sec 2)-1987*.

14.4 Mechanical Tests

14.4.1 The tests for mechanical requirements shall be carried out in accordance with **14** of IS : 3231 (Part 2/Sec 2)-1987*. In addition to the test conditions specified in **14.1.1** of IS : 3231 (Part 2/Sec 2)-1987*, the following conditions shall also be fulfilled:

a) For power relays at values of the characteristic quantity of zero for the initial value and a value declared by the manufacturer for the final value.

b) For directional relays at values of the input energizing quantities of zero for the initial values and rated values for the final values, with the angle between the two quantities being equal to the characteristic angle.

*Specification for electrical relays for power system protection: Part 2 Requirements for principal families, Section 2 General requirements for measuring relays.

(*Continued from page* 2)

Panel for the Revision of IS : 3231, ETDC 35/P9

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INTERNATIONAL SYSTEM OF UNITS (SI UNITS)

Base Units

Quantity	*Unit*	*Symbol*
Length	metre	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Thermodynamic temperature	kelvin	K
Luminous intensity	candela	cd
Amount of substance	mole	mol

Supplementary Units

Quantity	*Unit*	*Symbol*
Plane angle	radian	rad
Solid angle	steradian	sr

Derived Units

Quantity	*Unit*	*Symbol*	*Definition*
Force	newton	N	1 N = 1 $kg.m/s^2$
Energy	joule	J	1 J = 1 N.m
Power	watt	W	1 W = 1 J/s
Flux	weber	Wb	1 Wb = 1 V.s
Flux density	tesla	T	1 T = 1 Wb/m^2
Frequency	hertz	Hz	1 Hz = 1 $c/s(s^{-1})$
Electric conductance	siemens	S	1 S = 1 A/V
Electromotive force	volt	V	1 V = 1 W/A
Pressure, stress	pascal	Pa	1 Pa = 1 N/m^2